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Avoiding Anchorage Problems With Resin-Grouted Roof Bolts

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UNITED STATES DEPARTMENT OF THE INTERIOR

Report of Investigations 9129

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UNIT OF MEASURE ABBREVIATIONS USED IN THIS REPORT

cm^3	cubic centimeter	lb	pound
°F	degree Fahrenheit	lb/in	pound per inch
ft	foot	min	minute
g	gram	pct	percent
gpm	gallon per minute	psi	pound per square inch
in	inch	rpm	revolution per minute
in-lb	inch pound	s	second
kip/in	kip per inch	yr	year

AVOIDING ANCHORAGE PROBLEMS WITH RESIN-GROUTED ROOF BOLTS

By Howard C. Pettibone[1]

ABSTRACT

Mine safety personnel reported occurrences of excessive "glove-fingering" and other problems with resin-grouted roof bolt installa tions. To study these problems, the Bureau of Mines designed a test plan to (1) obtain baseline information on several resin cartridges and (2) investigate the variables involved in the installation of a resin bolt. Three brands of resin representative of the industry in January 1983 were selected for cartridge evaluation. The installation variables selected for study were the method of installation, the hole depth, and the hole annulus. These variables were studied by installing a series of bolts in concrete blocks using different values for each variable. Results of the research show overspinning the resin may cause problems, but they can be avoided by using the spin times recommended by manufacturers. Excessive glove-fingering is not a problem if the manufacturer-recommended installation procedures are followed.

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INTRODUCTION

Mine safety personnel reported that occasionally they had observed occurrences of excessive "glove-fingering" and of grout not encasing bolts the full depth of the hole. In this report, the term "glove-fingering" means that the plastic wrapper was visible on the outside of the hardened resin (1) after the resin-grouted bolt had been pulled out of the rock during a roof fall, or (2) after the bolt had been removed from the concrete block used in the project tests. The observations of the mine safety personnel were made in old, mined-out areas where roof falls had not been reported; consequently, there was no significant indication of problems in the fatal-accident reports. A brief review of the literature revealed that no research had been performed on glove-fingering and improper installation.

The most common bolt installation problems reported were that (1) mining companies were using a larger-diameter hole than had been specified for the cartridge, and (2) they were drilling holes deeper than required for the length of the bolt used. The worst procedure described involved pushing the bolt into the hole at high speed with no rotation until the plate was 1 in from the roof and then spinning the bolt. Apparently, this fast insertion tends to extrude grout from the collar of the hole. All personnel reported finding glove-fingering, but none considered it excessive. Several cautioned against regulations that might discourage the use of resin bolting. In one area of West Virginia, it was found that the use of resin bolting greatly reduced roof falls, making mining much safer in that particular district. Many of those interviewed questioned the quality of the resin cartridges available during 1982. Further investigation disclosed that some management misunderstood the procedures for proper bolt installation and that miners themselves were misinformed about the consequences of overspinning and unknowingly were reducing the anchorage capability of some resin bolts.

Based on the discussions with MSHA and industry personnel, the Bureau of Mines formulated a small project, using the expertise within the Spokane and Denver Research Centers, with the following objectives: Determine the causes of excessive glove-fingering or of insufficient grout with resin-grouted steel bolts, and demonstrate how to minimize these problems. A subsidiary goal of the research project was to determine, if possible, the effective length of resin-grouted bolts. Not all of these objectives were achieved; however, the causes and probable effects of some of the problems were identified. This report discusses the results of the project.

ACKNOWLEDGMENTS

Laboratory testing and data processing were performed by Dennis J. Cox and Joanne Johnston, engineering technicians, W. J. Smit, computer assistant, and Jill Zeer, student aid, all located at the Spokane Research Center (SRC). Raymond M. Statehan, supervisory geophysicist, Denver Research Center, assisted with the project formulation.

RESEARCH METHOD

A test plan was designed to investigate two major aspects of the problem: (1) evaluation of the resin cartridges and (2) investigation of the variables involved in the installation of a resin bolt. To evaluate the resin cartridges, samples of three brands of resin representative of those available to the mining industry in January 1983 were obtained. Three installation variables were selected for evaluation: method of installation, hole depth, and hole diameter. To determine the behavior of the resin and the relative importance of each of these variables, a series of bolts was installed in concrete blocks.

CARTRIDGE EVALUATION

A minimum of 150 cartridges was purchased from each of three manufacturers; these cartridges were representative of the resin bolts produced and available in January 1983. Two 2-ft-equivalent cartridges were ordered for a 1-in-diam hole. It was requested that the cartridges have a 1-min gel time and a minimum shelf life of 1 yr. Each cartridge was weighed to within 0.01 g, its length was measured to 1/16 in, and the diameter was determined with a dial gauge caliper to 0.001 in. Each cartridge was visually inspected for leaks at the end, moisture or stickiness on the sides, discoloration, breaks, or any other unusual aspect. Samples of hardened resin were made from each brand of cartridge, and the specific gravity of the hardened resin was determined using ASTM Test Designation C127-81, "Specific Gravity and Absorption of Course Aggregate." Toward the end of the study, 20 cartridges from each brand were tagged with their weight for a long-term evaluation of shelf life.

PRELIMINARY TESTS

In order to investigate variables of installation, resin bolts were inserted in concrete blocks measuring 2 ft by 2 ft in cross section and 4.5 ft long. The block testing method was selected because, after a bolt was installed by a given procedure, the block could be split open and the quality of the installed fixture could be visually examined. The blocks were installed on a steel frame where they could be drilled with a mast-type roof bolter. The bolts were tested in the same frame, as shown in figure 1. The roof bolter shown in figure 2 was mounted on a small frame that could be moved with a hand-operated hydraulic pallet lifter. Power was supplied to the roof bolter by a 10-gpm hydraulic pump. The bolter was equipped with adjustable needle valves, so that the maximum thrust, torque, and speed could be set to the desired levels. During this study, the maximum values measured were about 3,600 lb of thrust, 900 in-lb of torque, and a speed of 500 rpm.

To define the variables that needed investigation and to complete the design of the main test plan, 50 preliminary and special tests were performed. It was originally intended to use the Bureau's resin bolt bond tester to evaluate the quality of the bolt installation, but the device was not available when the block tests were performed (early 1983). Consequently, the two evaluation procedures used throughout the program were pullout tests and visual examinations of the bolts after removal from the block.

FIGURE 1.—Test frame.

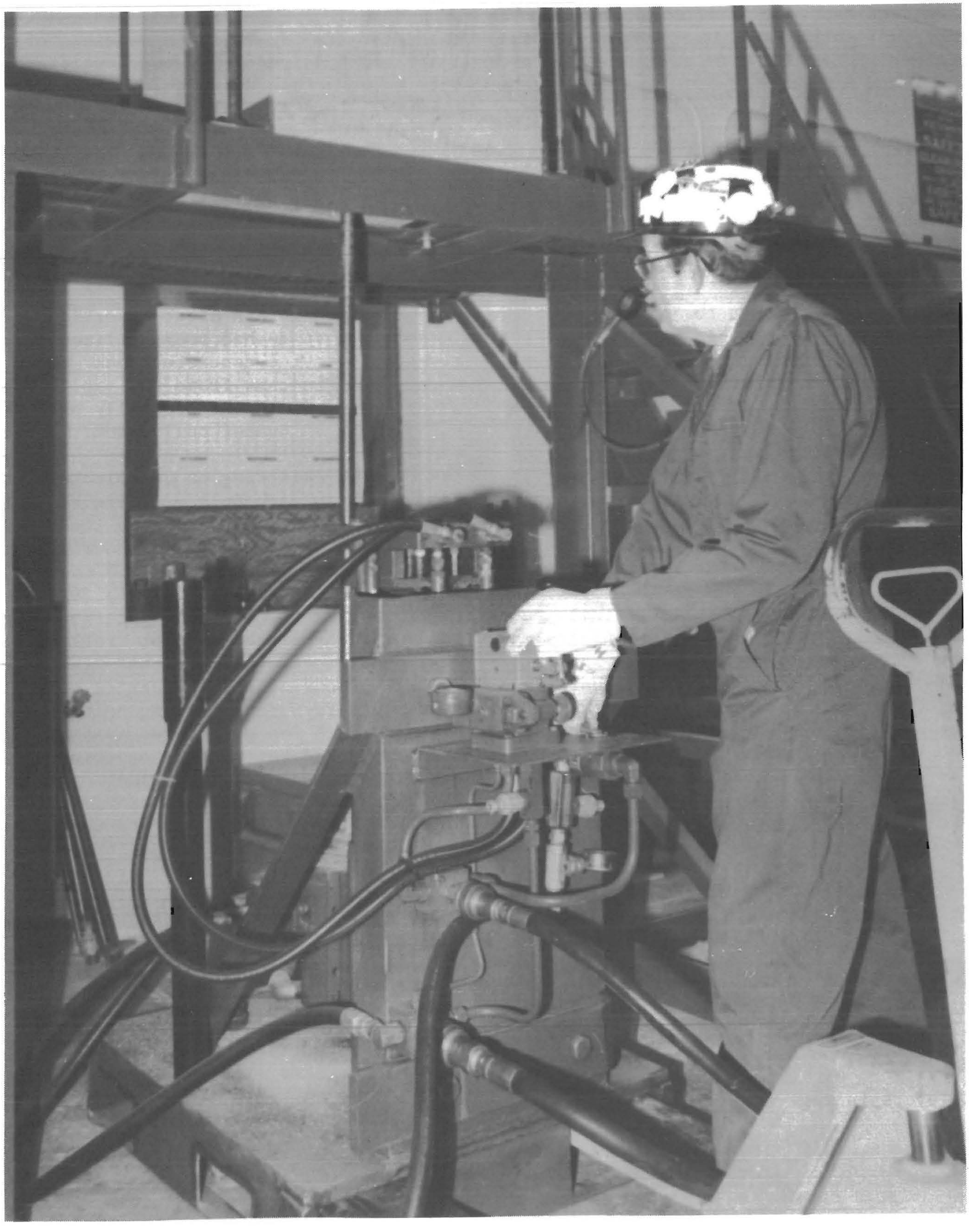

FIGURE 2.—Roof bolter.

Pull-tests were performed using the equipment shown in figure 3. The hydraulic center pull jack, pull rod, crows foot, and A-frame shown in figure 4 were installed on the pull collar about 5 min after the bolt had been installed. Each pull-test was begun 10 min after installation unless otherwise noted. Movement of the head of the bolt was measured with a linear-position transducer mounted on an adjustable photographic monopod. The hydraulic pressure was monitored with a pressure transducer. Signals from both transducers were fed to an X-Y plotter (fig. 3), which produced load deflection curves for each bolt tested. A sample curve with calculations of the yield load, P_y, and the stiffness, K, is given in figure 5. First, the pen was adjusted to zero on both axes, then load was applied with the hand pump until failure occurred or until the limit of the equipment was reached.

Eight preliminary tests were performed to determine how extreme installation procedures might influence the results of the tests and to establish final test procedures. The first extreme installation procedure involved the insertion into a block of a 4-ft bolt using one cartridge from each of three brands of resin with no rotation during the push and no spin after the push was completed. The other extreme installation procedure involved an attempt to overspin the bolt. The first overspin test was attempted with a 4-ft bolt, but the drill stalled after 20 s of spinning. The test was repeated with a 2-ft bolt, and the roof drill did have sufficient torque to overspin a 2-ft bolt. The overspinning procedure was then conducted with 2-ft bolts using all three brands of resin. The bolt was rotated slowly while it was inserted, and then maximum torque was applied with the head of the bolt close to the block until the resin was destroyed by overspinning.

To detect any differences between the three brands of resin, a series of 30 tests was designed. These consisted of 1-ft column tests using a 2-ft-long, 3/4-in-diam (Grade 40) rebar bolt. One foot of resin was retained in the top end of the hole by welding a 1/8-in-wide steel ring to the rebar at the 12-in mark and then wrapping friction tape around the ring to make a bushing to retain the resin in the hole. Each of these bolts was installed according to the manufacturer's recommendations, and a pull-test was performed 10 min after insertion.

When all space had been utilized in a given block, the concrete block was removed from the test frame and split open using conventional mechanically anchored bolts and a center pull jack. Occasionally, a 20-lb sledge hammer was used to complete splitting of the blocks. The condition of each bolt was visually inspected as it was removed from the block. These data were recorded manually and photographically.

At the end of this series of 30 tests, the investigator became concerned that using cut cartridges did not reflect actual conditions of use by the mining industry. Consequently, a series of eight tests was run on 1-ft-long bolts. One area in which the procedure deviated from industry practice was the cutting of a cartridge to get a 1-ft column of grout. The cartridge was cut and inserted in the hole with the open end to the top. Apparently, a better practice is to use a cable tie to seal the cartridge at the cut. Ten tests were run using manufacturer's recommended installation procedures: four with both ends of the cartridge sealed, and six with only the bottom end of the cartridge sealed. Two brands of resin were used, nine cartridges from brand C and only one cartridge from brand A.

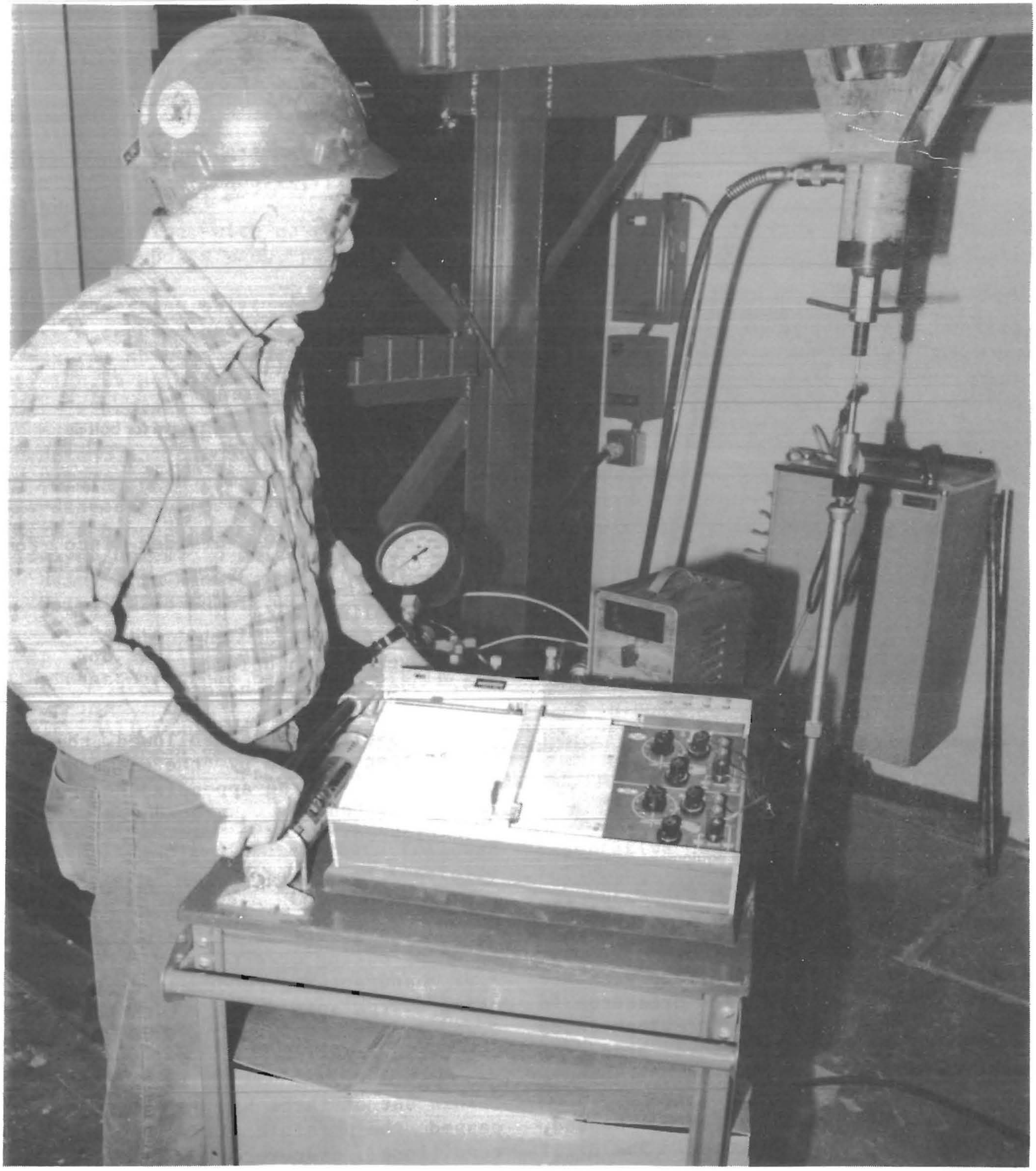

FIGURE 3.—Pull-test equipment.

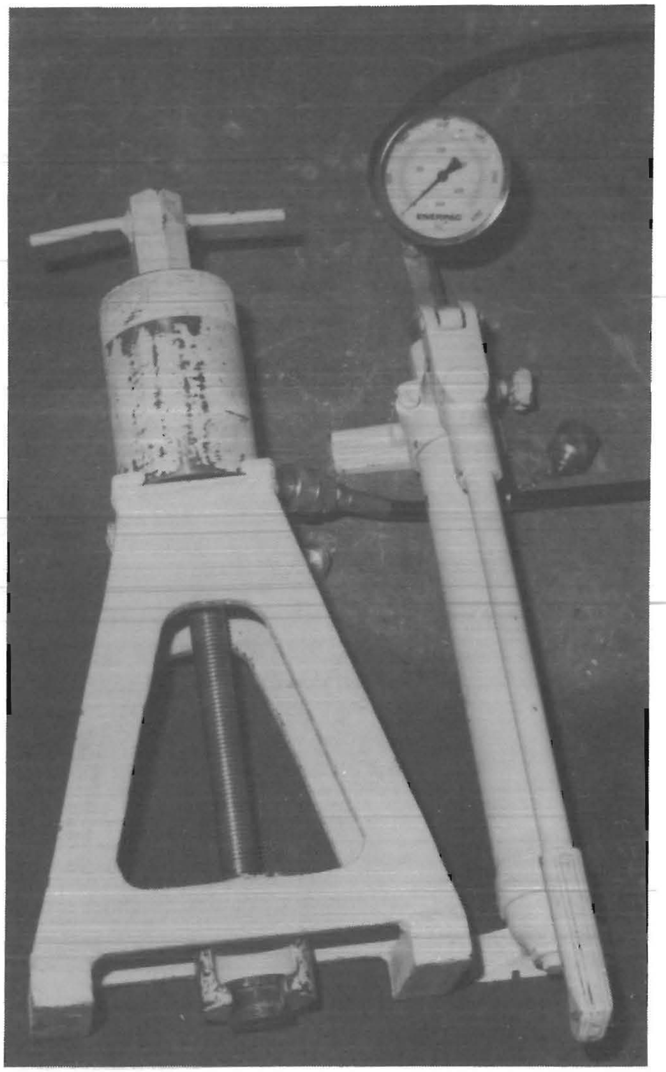

FIGURE 4.—Hydraulic pulling equipment.

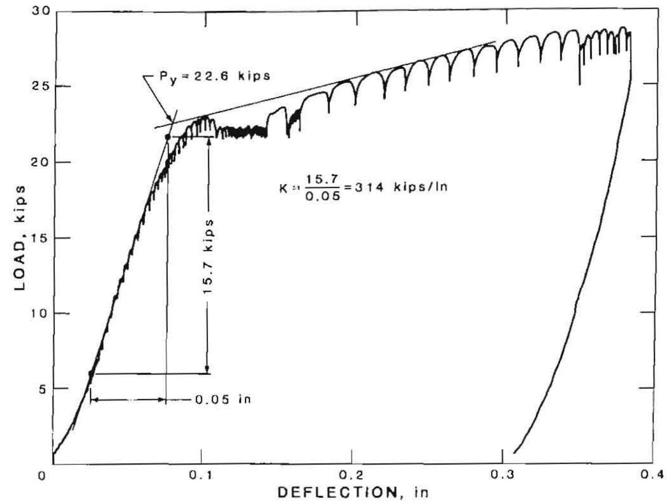

FIGURE 5.—Load-deflection curve for bolt 59.

MAIN TESTS

The preliminary test provided adequate data to design the test plan presented in table 1. All of the main block tests were conducted on each of three brands of resin. The standard length of the hole was 1 in longer than that of the bar. A 4-ft, Grade 40, No. 6 (3/4-in) headed, deformed, rebar bolt was used. The drill bit was measured with a micrometer before each test hole was drilled, and the diameter of each hole was checked with a hole caliper. To keep the bolt length the same, a pull collar was placed on every bolt, although only 20 to 40 pct of the bolts in each group underwent pulltests.

The test plan was divided into four major categories:

1. Baseline tests
2. Bad procedures
3. Over-length holes
4. Over-diameter holes

The baseline tests followed the procedures recommended by the manufacturers (summarized in the appendix). The following faulty procedures were investigated:

1. Fast insertion with no rotation, followed by 12-s spin.
2. Slow insertion of the bolt with no spinning during or after insertion.
3. Manufacturer-recommended insertion using 60-rpm spin during insertion, followed by maximum spinning (500 rpm) until the bolter stalled.

This set of three bad procedures encompassed the possible range of worst-case conditions discovered in interviews and personal observations. The over-length hole test utilized the manufacturer-recommended procedures for each of the three brands. The only variable was the length of hole, which was 2, 3, and 4 in longer than the length of the bar. The baseline test had a hole length 1 in past the end of the bar, giving a hole-length

TABLE 1. - Test plan

Test and methodology	Test nos.	Total bolts	Total pull-tests
Baseline tests:			
Mfr.'s procedure: 5 bolts each from 3 resin brands; pull[1] of each brand	51-72	15	3
Bad procedures:			
Fast insertion, with no rotation, followed by 12-s spin: 10 bolts each, pull 2 of each	73-102, 170-172	30	6
Slow insertion only: 5 bolts each, pull 2 of each	103-118	15	6
Mfr.'s recommended insertion with 60-rpm spin, then max rpm spin to stall: 5 bolts each, pull 2 of each.	119-133	15	6
Over-length holes:			
Mfr.'s procedure: 3 bolts each, pull 1 of each:			
Hole 2 in longer than bar	NAp	9	3
Hole 3 in longer than bar	NAp	9	3
Hole 4 in longer than bar	NAp	9	3
Over-diameter holes:			
Mfr.'s procedure, starting with new bit and using for only 3 holes: 3 bolts each, pull 1 of each:			
Using 1-in starter bit (1-1/16-in)	161-169	9	3
Using 1-1/8-in bit	([1])	([1])	([1])
Total	NAp	111	33

NAp Not applicable.
[1]No test performed because 1-1/8-in bit unavailable.

NOTE.--All standard holes 1 in longer than bar. Bolts are 3/4-in, Grade 40, headed, deformed rebar bolts. Gauge each hole and measure bit used in each hole with a micrometer. Place a pull collar on every bolt.

variable of 1 to 4 in. in 1-in increments. The hole-diameter tests followed manufacturers' procedures, and initially used three bit sizes. With the exception of the hole-diameter tests, a standard 1.030-in finishing bit was used in all tests. New 1-1/16-in-diam starter bits were used in the hole-diameter tests for each series of three tests. Because the 1-1/8-in bit was not available, only two hole diameters were tested: 1.030 in and 1-1/16 in.

Tension tests were performed on representative samples of the rebar bolts following the ASTM Test Designation E8-78, "Standard Methods of Tension Testing of Metallic Materials." The concrete used in the test blocks was a pea gravel mix with a design strength of 4,500 psi at 28 days. The sampling of the concrete and the casting of the cylinders followed ASTM standard procedures.

TEST RESULTS

INITIAL CARTRIDGE EVALUATION

The brand A cartridges were the neatest, cleanest, and most attractive of the three brands. They were also the most uniform in size and weight. Each cartridge was clean, and the ends were crimped tight. The statistical results of the measurements are in table 2. The brand B cartridges were also clean and neat with tightly crimped ends. The ends on the brand C cartridges were not crimped tight; consequently, the cartridges were very messy and sticky to handle. The plant where the brand C cartridges were made has since adjusted its

TABLE 2. - Cartridge weight and length data

Brand	Minimum	Maximum	Average	Std dev
Weight, g:				
A	338.14	350.98	344.37	2.34
B	305.73	334.99	318.06	6.14
C	319.27	342.71	333.04	4.56
Length, in:				
A	16.938	17.125	17.003	0.031
B	16.1875	17.1875	16.77	0.196
C	16.563	17.563	17.155	0.201

NOTE.--The diameter was uniform for each individual brand and, therefore, is not included in this summary.

packaging machine and eliminated the leaking cartridges. While there are some variations in lengths and weights, the amount of resin in a brand A cartridge is sufficient to fill a reasonably uniform hole, but the amount is probably not sufficient in brands B and C, as demonstrated by calculations and by the 2- and 4-ft tests.

SAMPLE CALCULATIONS

For a 1.030-in-diam bit, the following volumes are required for laboratory testing:

Hole depth = 48 in;

Bar length in hole = 47 in.

$$\text{Volume of annulus} = \frac{\pi}{4}(1.030^2 - 0.75^2)(47)(2.54)^3 + \frac{\pi}{4}(1.030^2(1)(2.54)^3,$$

$$= 301.48 + 13.65,$$

$$= 315.14 \text{ cm}^3,$$

$$= + 10 \text{ pct} = 346.65 \text{ cm}^3.$$

The additional 10 pct accomodates voids in a 4-ft hole.

Weight per 2-ft equivalent cartridge

Brand	Sp gr	Weight, g	
		Calculated[1]	Weighed
A	1.84	319	344
B	2.02	350	319
C	2.00	346	330

[1]Weight = 1/2(346.65) x specific gravity.

LONG-TERM CARTRIDGE EVALUATION

In June 1984, 17 months after the initial cartridge evaluation, the 20 tagged cartridges from each brand were evaluated. During these 17 months, the cartridges were stored in the laboratory at an approximate temperature of 65° F (maximum 75°, minimum 55°). A comparison of the initial and final weights, lengths, and diameters (table 3) shows that brands A and B had a weight loss but brand C did not. The apparent

TABLE 3. - Long-term cartridge evaluation

Brand	Minimum	Maximum	Average	Std dev
Weight, g:				
Brand A:				
Initial	341.59	349.48	344.285	2.25
17-month	326.96	337.00	331.02	3.21
Brand B:				
Initial	308.91	332.09	319.22	6.77
17-month	280.45	331.99	316.53	11.38
Brand C:				
Initial	323.22	335.01	330.12	4.17
17-month	323.26	335.12	330.11	4.29
Length, in:				
Brand A:				
Initial	16.9375	17.0625	17.0000	0.029
17-month	16.875	17.250	17.04	0.091
Brand B:				
Initial	16.5625	17.125	16.81875	0.18
17-month	16.5625	17.25	16.90	0.16
Brand C:				
Initial	16.6875	17.25	17.01	0.21
17-month	16.75	17.3175	17.04	0.19
Diameter, in:				
Brand A				
Initial	0.90	0.90	0.90	([1])
17-month	0.703	0.948	0.890	0.054
Brand B:				
Initial	0.865	0.865	0.865	([1])
17-month	0.778	0.934	0.858	0.036
Brand C:				
Initial	0.87	0.87	0.87	([1])
17-month	0.838	0.914	0.878	0.025

[1]Standard deviation of $<10^{-9}$.

but insignificant increases or decreases in lengths and diameters is attributed to the fact that the measurements were made by different technicians. The cartridges were also dissected to examine the resin and hardener for deterioration with time. Six cartridges of brand A, five of brand B, and two of brand C were dissected. The resin set times for two of each brand were measured. The cartridge was cut, material was extruded and then mixed with a wood spatula, and the set time was measured with the following results: brand A, 60 and 72 s; brand B, 35 and 45 s; and brand C, 60 and 90 s. The technician performing the dissection wrote the following:

Brand A: "Resin extrudes but catalyst is stiff and brittle (it does not mix) catalyst powders up. All the water has evaporated from catalyst, chalklike appearance."

Brand B: "Catalyst excellent shape, resin also in good shape, very sticky, good fast, reaction."

Brand C: "Catalyst and resin are so stiff it is difficult to get out of cartridge (stick broke). Resin is so stiff it is difficult to impossible to mix, stinks."

From the statistics and the technician's notes, it is evident that trying to use resin more than a year old or that has not been properly stored will result in poorly installed bolts. While one brand appeared to be still good after 17 months of storage, the other two definitely were bad. If there had been any doubt prior to this, the Bureau's work should convincingly demonstrate that the 1-yr storage limit for resin cartridges must be respected. If cartridges have been stored in a warm place or handled roughly so as to break any of them, they should not be used.

PRELIMINARY TESTS

As stated earlier, glove-fingering means that the plastic wrapper was observed on the outside of the hardened resin when the resin-grouted bolt was removed from the concrete block. As shown in figure 6, the plastic wrapper almost completely encircled the full circumference of the resin-rock interface.

Failure of the bolt system is defined by the following maximum pull-test bolt load (yield load):

Bolt condition	Yield load (P_y), kips
Failure...........	≤ 7
Doubtful..........	≥ 7, ≤ 19
Satisfactory......	≥ 19

To apply this criterion to bolt pulltests, the yield and tensile strength of the bolts being used must be known. This criterion *only* applies to laboratory bolt tests in 4,500-psi concrete blocks. It has not been field tested and *should not* be applied to field tests.

The results of the three preliminary tests (for bolts 1, 4, and 5) are presented in table 4, where the bolt was only pushed into the block with no spinning at any time during insertion. Bolt 1 had a very low pull load of 6.2 kips and an equally low stiffness of 92 kips/in. Visual inspection after block splitting revealed that the resin on the entire length of this bolt was soft and uncured and that the top 23 in (out of 48) were glove-fingered. Bolt 1 is shown at the top of figure 7. Bolt 4 was installed in the same manner as bolt 1, but the results were entirely different even though the top 27 in had

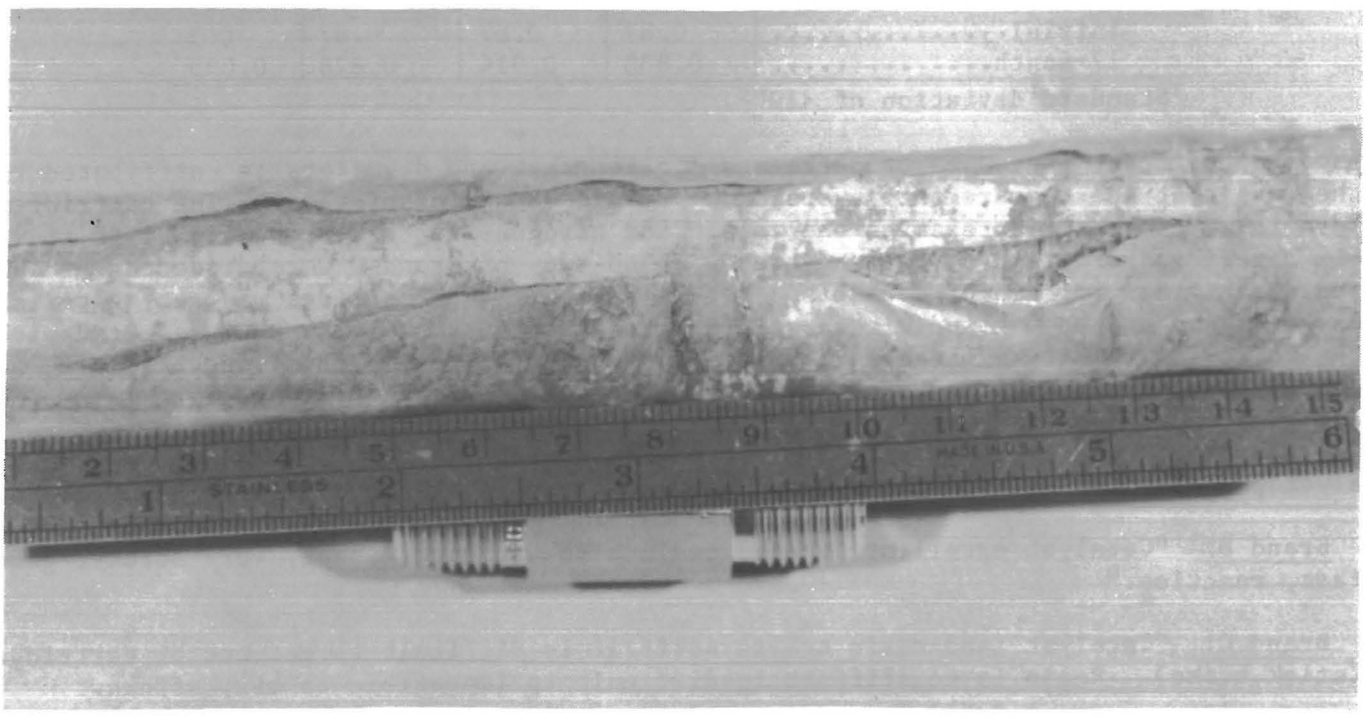

FIGURE 6.—Full glove-fingering on bolt 73.

TABLE 4. - Preliminary tests--load and stiffness data

Bolt no.	Brand	Installation method	Bolt length, ft	10-min test: Yield load (P_y), kips	10-min test: Stiffness (K), kips/in	1-day test: Yield load (P_y), kips	1-day test: Stiffness (K), kips/in	Comments
1.....	C	Push only........	4	6.2	92	7.9	140	Straight push, no spin; failed.[1]
2.....	C	Attempt overspin.	4	22.5	356	NAp	NAp	Stalled at 20 s into spin; okay, looked excellent.
3.....	C	Overspin 55 s....	2	4.7	78	6.2	123	Failed.[2]
4.....	A	Push only........	4	24.7	192	NAp	NAp	Top 27 in glove-fingered; okay.
5.....	B	..do.............	4	14.0	178	16.8	268	Top 15.5 in glove-fingered; entire length soft and sticky; failed.
6.....	B	Overspin 41 s....	2	3.3	26	NAp	NAp	Pulled bolt out of block.[2]
7.....	B	Overspin 25 s....	2	3.0	54	5.4	182	Failed.[2]
8.....	A	Attempt overspin.	2	20.2	220	20.2	220	Resin stalled drill at 17 s; okay; pull-test had indicated good bolt.[3]

NAp Not applicable.

[1]All resin uncured; bottom 18 in soft and sticky and remainder soft. Top 23 in glove-fingered.

[2]Resin at bar-and-resin interface was a light-gray powder; remainder was okay.

[3]Visual inspection after opening block: bottom 18 in just a light-gray powder on bar; some hardened resin still clinging around top 6 in of bolt.

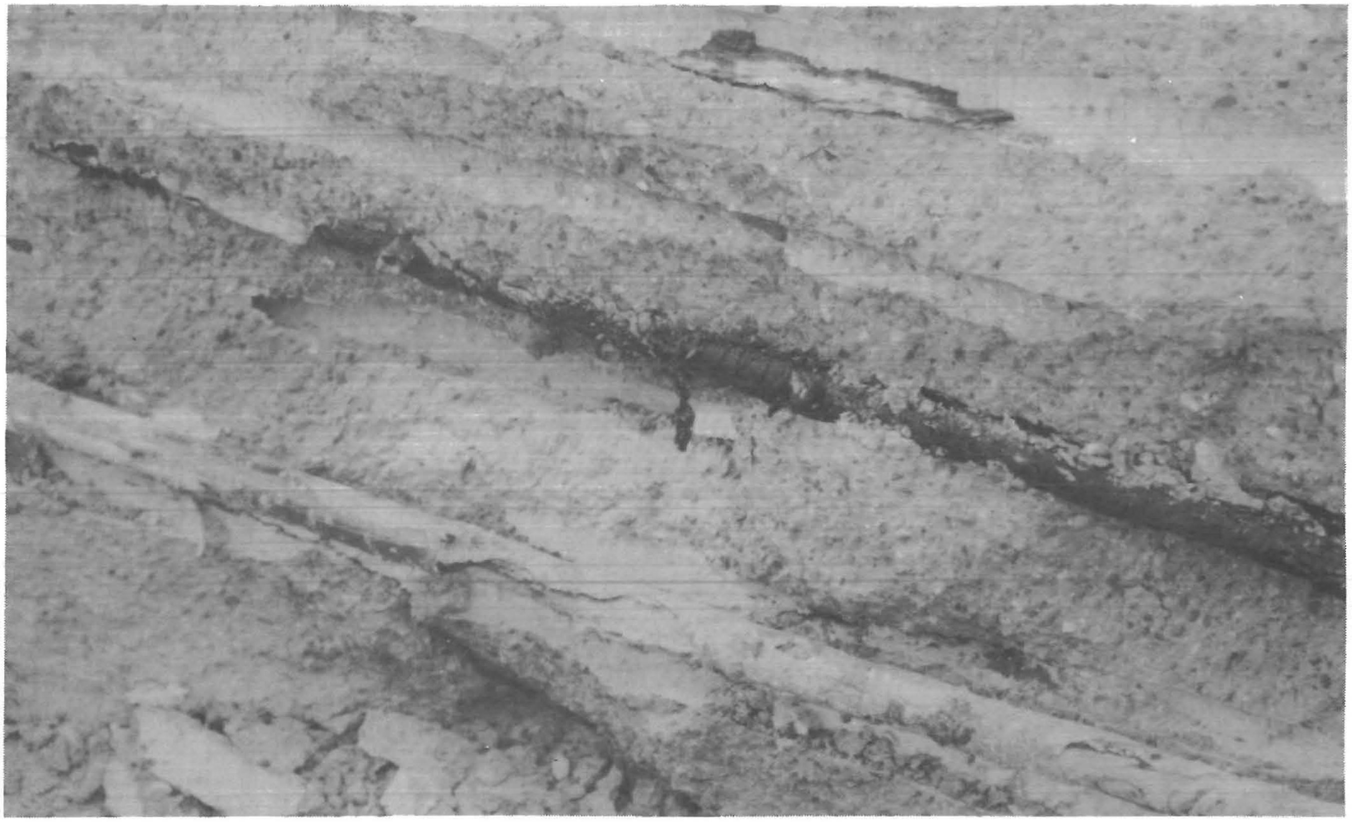

FIGURE 7.—Bolt 1 (top) and bolt 2 (bottom) in split-open block.

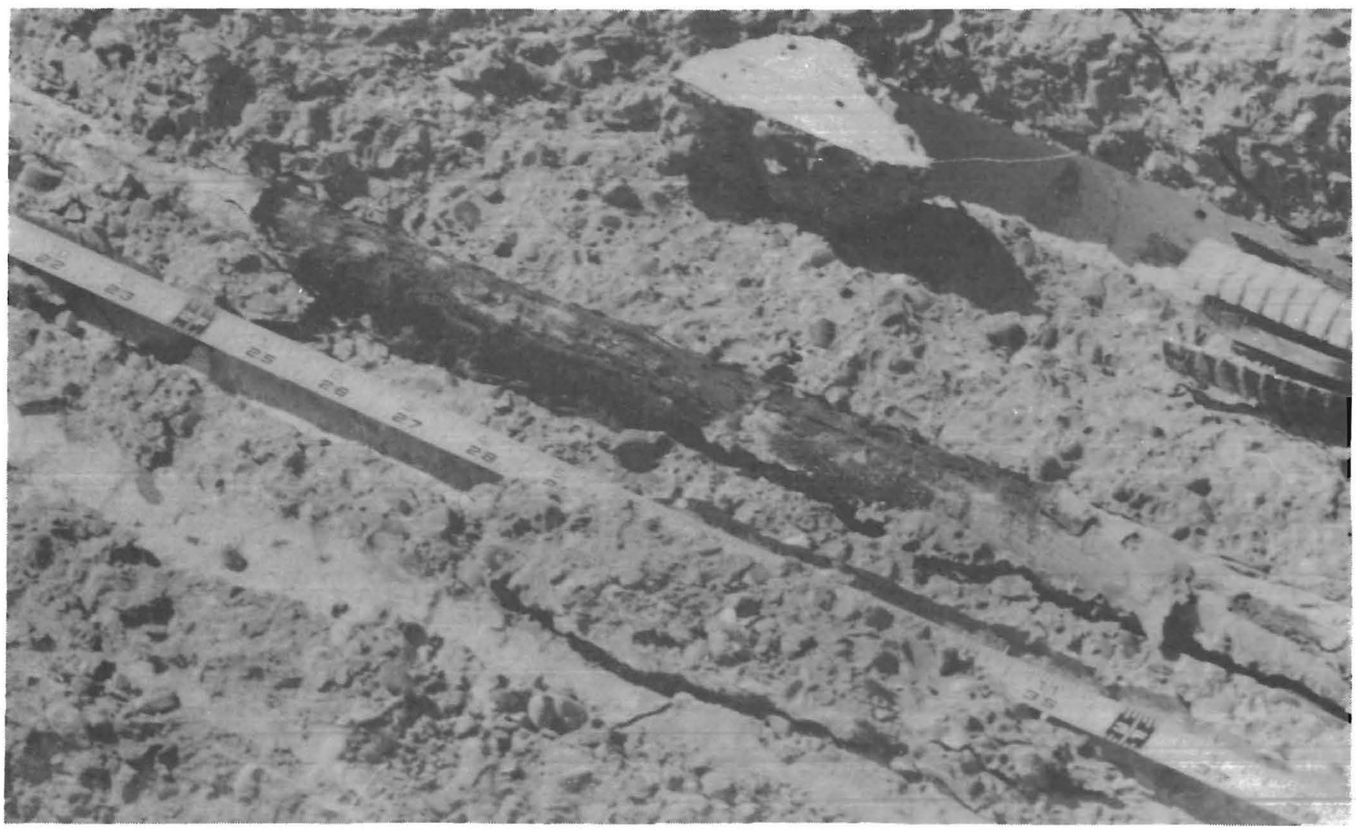

FIGURE 8.—Soft, sticky uncured resin on bolt 5 at 24 to 33 in from top end of bolt.

glove-fingering. The results of the pull load and stiffness tests were in the normal range of a good bolt. This dramatically illustrates the fact that a bolt can be poorly installed, with only the top 20 in out of 47 in having any ability to support load, and yet a pull-test can indicate that it is an excellent bolt. Figure 8 shows an area of bolt 5 (between 24 and 33 in from the top end) where the resin is very soft, sticky, and uncured. Examination of the data on bolt 5 (table 4) also shows that it had poor results in pull load and stiffness tests and that it failed.

The results of the five overspin tests are also given in table 4. Bolt 2 was the first overspin attempted, and the laboratory roof bolter stalled at 20 s. This produced an excellent bolt: The visual inspection showed good, well-cured resin, and the pull-test indicated the same. The length of the bolt was reduced to 2 ft for bolt 3, and it was possible to overspin it for a total of 55 s. A light-gray powder thought at first to be concrete, but found later to be granulated resin destroyed by the overspinning, sifted out of the collar of the hole. The load of 4.7 kips and a stiffness of 78 kips/in indicated that the bolt failed. The results of the block split are graphically illustrated in figure 9. Note that the zone of light-gray resin marked on figure 9 is approximately the depth of the deformations on the bar. This zone of resin at the bolt-resin interface was converted to a light-gray powder by excessive spinning, but the surrounding annulus of resin at the concrete-resin interface was a firm, dark gray, excellent quality resin. Bolt 6 was spun a total of 41 s, and both the pull-test and the visual examination indicated that the bolt had failed. This bolt was actually removed from the block

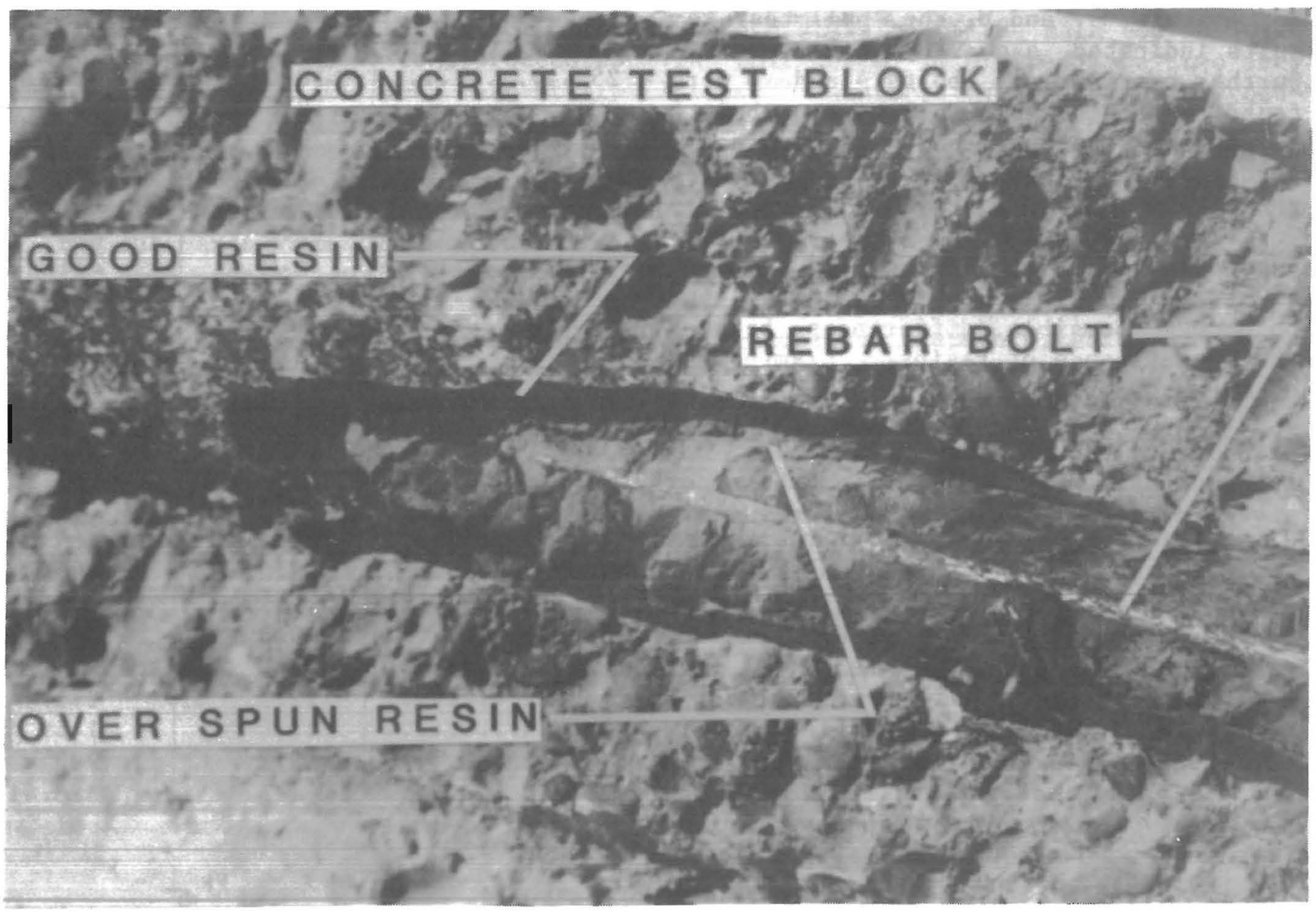

FIGURE 9.—Destroyed resin at bolt resin interface on bolt 3.

with the pull-test apparatus. The installation procedure for bolt 7 repeated that of bolt 6, but spinning was stopped 5 s after the bolter slowed (25 s), for a total spin time of 30 s. This also produced a failed bolt, as demonstrated by the results of the pull-test and the visual observations. Bolt 8 stalled the drill at 17 s, and this produced a good bolt based on pull-test results. However, the visual inspection found a light-gray powder on the bar for the lower 18 in with some hardened resin clinging to the bar and to the concrete-resin interface. About 6 in of hardened resin and 18 in of granulated resin were sufficient to indicate that, on the basis of the pull-test, the bolt was good; however, this was a bad bolt that in a mine could give a false sense of security.

The results of these eight tests dramatically indicate that a pull-test is not an adequate means of evaluating the strength of a resin-grouted steel bolt. For bolts 2, 4, and 8, the pull-test results indicated a quality bolt, but on further examination, bolts 4 and 8 were found to be bad. The pull-test on bolt 5 suggested that the bolt was marginally good, but the visual examination revealed that it was poor.

Table 5 summarizes the load and stiffness data for thirty 1-ft-column tests on a 2-ft bolt. These tests were designed to detect possible differences between the three brands of resins. Examination of the statistical summaries indicate no significant differences between the three brands. Although the mean values for load and stiffness declined in the order given in table 5, the differences were too small to be significant. The examinations found no full glove-fingering along the 1-ft column for any of the brands; however, brand A had one case of partial glove-fingering, brand B had eight, and brand C had four. Even on a 1-ft column test, this glove-fingering is not recorded in the data from the load and stiffness tests. This reinforces the previously drawn conclusion that a load test is not an adequate means of evaluating the resin bolt.

TABLE 5. - Load and stiffness data for 1-ft-column test on 2-ft bolts

Bolt no.	Yield load (P_y), kips	Stiffness (K), kips/in
BRAND A		
10	21.5	236
11	21.5	272
12	23.5	240
13	19.0	247
14	21.5	243
15	20.0	256
16	21.5	232
17	19.0	265
18	20.0	242
19	18.0	211
Max	23.5	272
Min	18.0	211
Mean	20.6	244
Std dev	1.64	17.3
BRAND B		
20	19.5	222
21	19.0	225
22	22.0	222
23	19.5	256
24	20.5	252
25	18.0	206
30	18.5	254
31	20.5	208
32	19.5	234
33	19.5	214
Max	22.0	256
Min	18.0	206
Mean	19.6	229
Std dev	1.13	18.90
BRAND C		
29	19.5	204
34	22.5	227
35	18.0	197
36	19.0	183
37	17.0	145
38	19.0	216
39	18.0	198
40	19.5	204
41	19.0	238
42	20.0	225
Max	22.5	238
Min	17.0	145
Mean	19.2	203
Std dev	1.47	26.41

TABLE 6. - Load and stiffness data for 1-ft-column test on 1-ft bolts

Bolt no.[1]	Yield load (P_y), kips	Stiffness (K), kips/in	Sealing of cartridge ends
26	16.0	248	Bottom only.
27[2]	21.0	250	Do.
28	14.0	223	Do.
43	([3])	([3])	Both.
44	18.5	210	Bottom only.
45	23.0	263	Both.
46	([4])	([4])	Bottom only.
47	20.0	319	Do.
48	18.0	233	Both.
49	22.5	300	Bottom only.
50	20.0	261	Both.
Max	23.0	319	NAp.
Min	14.0	210	NAp.
Mean	19.2	256	NAp.
Std dev	2.9	35	NAp.

NAp Not applicable.
[1]Brand C except as noted.
[2]Brand A.
[3]Extensometer not aligned with bolt.
[4]Release valve leaked.

The fact that the load and stiffness strengths were slightly less for Brand C than for the other two brands induced the Bureau to reexamine its test procedures for the 1-ft test. The load and stiffness data for the 10 special tests are shown in table 6. As discussed previously, the resin cartridges were cut to produce a 1-ft-equivalent cartridge. Some of the cut ends were left open, while others were sealed with cable ties. Neither the load and stiffness data nor a visual examination of the bolts (figs. 10-11) show any clear-cut difference between the method of sealing both ends or that of sealing only the bottom end of the cartridge.

MAIN TESTS

The discussion of the main body of resin bolt tests is divided into two sections "Manufacturer-Recommended Procedures" and "Bad Procedures." Included under the manufacturers' procedures are the baseline tests, tests that followed the recommended procedures with subsequent spinning of the bolt until the roof bolter stalled, and tests of bolt installation in overly long holes and in holes with excessive diameters, which also used the recommended procedure except for the variations in length and diameter of the holes. All of the foregoing exceptions from the manufactuers' recommendations

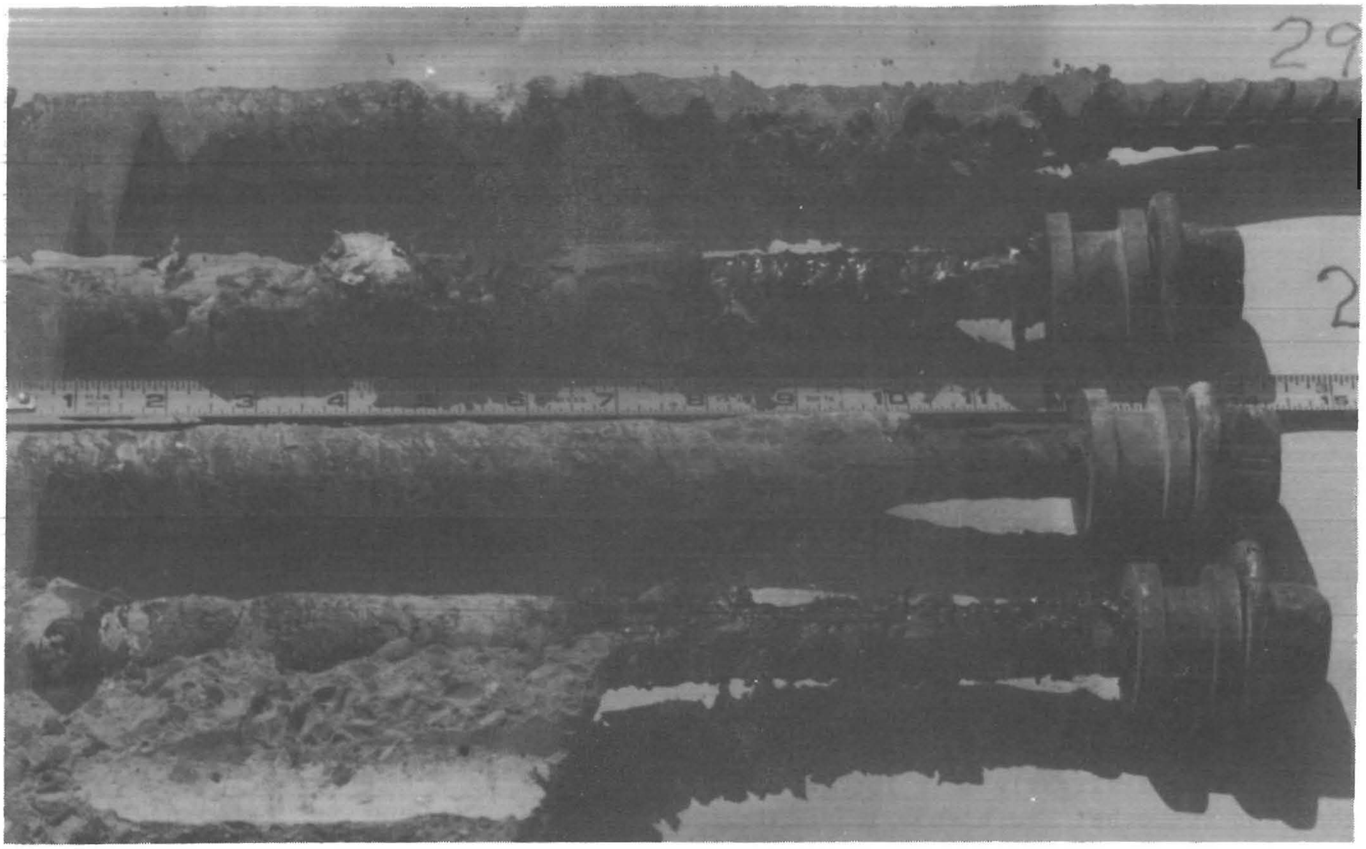

FIGURE 10.—Bolts 26 through 29 after removal from block.

still produced acceptable test results. The section on bad procedures includes procedures that entail fast (2 s) or slow (between 12 and 18 s) installation of bolts. Although the test that consisted of following recommended procedures but spinning until the drill stalled was listed in the test plan under "Bad Procedures," it did not produce a bad bolt. Therefore, in this section, it has been listed under "Good Procedures." Full glove-fingering, as used in tables 7 to 12, means that the plastic wrapper almost completely encircled the full circumference of the resin-rock interface. Partial glove-fingering indicates that there is some wrapper at the resin-rock interface.

Manufacturer-Recommended Procedures

The amount of glove-fingering that occurred when the manufacturers' recommended procedures were followed (tables 7 to 9) varied greatly among the three different brands of resin. Brand B exhibited glove-fingering in 1 out of 22 tests; brand C had glove-fingering in 4 out of 24 tests. These incidences of glove-fingering are considered to be minor. On the other hand, Brand A had glove-fingering in 22 out of 25 tests. In the one brand B case, the length of full glove-fingering was limited to 5 in. In the four instances of glove-fingering with brand C, the length never exceeded 9 in. The length of full glove-fingering

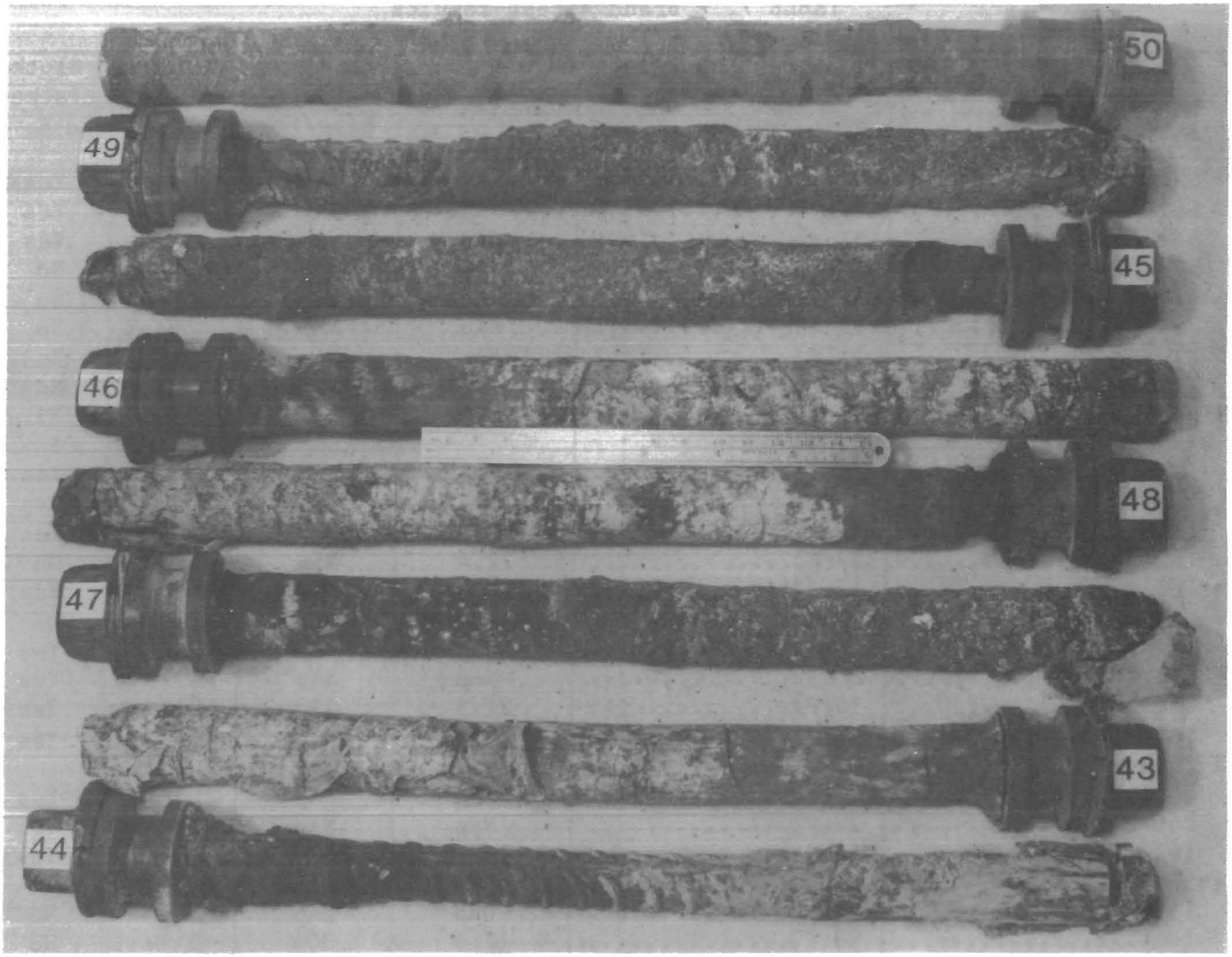

FIGURE 11.—Bolts 43 through 50 after removal from block.

exhibited by brand A cartridges varied from a minimum of 3 in to a maximum of 27 in. In 4 of the 22 instances, the length of glove-fingering exceeded 50 pct of the length of the bolt.

Even with these major instances of glove-fingering, there was no external test evidence to show that the resulting bolts would be ineffective. None of the pull-tests indicated a bad bolt even when 23 or 27 in of glove-fingering had occurred. Once again, the credibility of the pull-test as an evaluation of resin bolts must be questioned. Visual inspection did not indicate that the plastic casing had produced a slip plane capable of causing lowered bolt load. The results of the pull tests-listed in tables 7 to 9 indicate that all the bolts installed using the procedures recommended by the manufacturers were good bolts based on the evaluation criteria of this report. Visual observations verified this.

TABLE 7. - Brand A test results

Procedure and bolt no.	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked
Mfr.-recommended:					
63	0	NAp	NAp	NAp	Yes
64	0	NAp	NAp	NAp	Yes
65-67[1]	NAp	NAp	NAp	NAp	Yes
68	18(F), 18(P)	24.4	338	NAp	No
69	9(F), 3(P)	NAp	NAp	NAp	No
70	18(F)	NAp	NAp	NAp	No
71	11(F)	NAp	NAp	NAp	No
72	11(F), 3-1/2(P)	NAp	NAp	NAp	No
Mfr.-recommended plus spin to stall:					
127	10-1/2(F), 14(P)	NAp	NAp	8-1/2	Yes
128	8(F)	18.4	187	20-1/2	Yes
129	5-1/2(P)	NAp	NAp	17-1/2	Yes
132	27(F)	22.4	256	2-1/2	No
133	17-1/2(F)	NAp	NAp	12-1/2	Yes
2-in overdrill:					
134	10(F)	NAp	NAp	17-1/2	Yes
135	8(F)	NAp	NAp	15	Yes
136	10(F)	21.5	193	11	Yes
137	26(F)	NAp	NAp	14	Yes
3-in overdrill:					
150	15(F)	NAp	NAp	21-1/2	Yes
160	22(F)	NAp	NAp	11	Yes
161	15(F)	22	227	20-1/2	Yes
4-in overdrill:					
154	11(F), 12(P)	NAp	NAp	3	No
155	23(F)	17.5	304	6	No
156	13(F)	NAp	NAp	7	Yes
1-1/16 starter bit:					
167	3-1/2(F)	NAp	NAp	4-1/2	No
168	3(F), 9(P)	20.5	192	13-1/2	No
169	8(F)	NAp	NAp	11	No

NAp Not applicable. [1]Block split on insertion; no visual data recorded.

NOTE.-- F = full; P = partial.

The measurement of the length of void at the collar of the hole was useful for evaluating the effects of overlong holes or of holes with excessive diameters on the effectiveness of bolts. When inspecting the data in tables 7 to 9, the amount of void at the collar must be considered in conjunction with the data in the last column, which indicate whether or not the block cracked as the bolt was inserted. When the block cracked, resin escaped; therefore, those tests must be ignored when comparing data on the shortages of grout at the collar of the hole. After eliminating data from the tests where the block cracked, the remaining data show that using a starter bit can produce approximately the same amount of grout shortage (8 to 10 in) as is caused by drilling the hole 4 in longer than the bolt. This test reinforced manfacturer guidelines, which state that the hole diameter and the length of the hole are

TABLE 8. - Brand B test results

Procedure and bolt no.	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked
Mfr.-recommended:					
58....................	0...............	NAp	NAp	NAp	No
59....................	5-1/2 (P).......	22.6	314	NAp	No
60....................	5(F), 2(P)[1].....	NAp	NAp	NAp	Yes
61....................	0...............	NAp	NAp	NAp	No
62....................	9(P)............	NAp	NAp	NAp	Yes
Mfr.-recommended plus spin to stall:					
124...................	0...............	NAp	NAp	11	Yes
125...................	0...............	20.7	276	6	No
126...................	0...............	18.5	276	2	No
130...................	0...............	NAp	NAp	12	Yes
131...................	2(P)............	NAp	NAp	3-1/2	No
2-in overdrill:					
138...................	0...............	21.3	244	5	No
139...................	0...............	NAp	NAp	3 6(P)	No
140...................	0...............	NAp	NAp	NAp	No
3-in overdrill:					
147...................	0...............	NAp	NAp	8-1/2 2-1/2(P)	Yes
148...................	0...............	22.8	245	6-1/2 1-1/2(P)	Yes
149...................	0...............	NAp	NAp	8 3-1/2(P)	No
4-in overdrill:					
157...................	0...............	19.1	230	9	No
158...................	0...............	NAp	NAp	5 5(P)	No
159...................	2-1/2(P)........	NAp	NAp	11	Yes
Starter bit:					
164...................	0...............	20.2	309	6	No
165...................	0...............	NAp	NAp	12-1/2	No[2]
166...................	0...............	NAp	NAp	11-1/2	No[3]

NAp Not applicable. [1]3 spots.
[2]3 in soft and sticky, from 37 to 40 in from collar.
[3]3 in soft and sticky, from 36-1/2 to 39-1/2 in from collar.

NOTE.--F = full; P = partial.

critical to the performance of the resin bolt.

The problem with test blocks cracking, which was encountered during the testing, had not been anticipated during the planning stages of this project. Examination of these cracks revealed that any resin forced into a crack was uncured; i.e., uncatalyzed resin that did not bond the concrete together. Block cracking varied greatly according to the brand of resin. However, it must be noted that all of the brands have been modified since these tests were run; if the tests were repeated now, the results could be radically different. The data in tables 7 to 9 show that cracking of the blocks was a

TABLE 9. - Brand C test results

Procedure and bolt no.	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked
Mfr.-recommended:					
51	0	NAp	NAp	NAp	No
52	0	NAp	NAp	NAp	No
53	9(F)	NAp	NAp	NAp	No
54	0	NAp	NAp	NAp	No
55	2-1/2(P)	23.2	202	NAp	No
56	0	20.8	296	NAp	No
57	5(P)	22.9	290	NAp	No
Mfr.-recommended plus spin to stall:					
119	0	([1])	([1])	3	No
120	0	27.8	358	2-1/2	No
121	0	22.2	340	3	No
122	0	20.6	320	6	No
123	0	NAp	NAp	2	No
2-in overdrill:					
141	0	NAp	NAp	1, 3(P)	No
142	0	23.7	204	([2])	No
143	7-1/2(P)	NAp	NAp	([2])	No
3-in overdrill:					
144	7(F)	23.2	252	([2])	No
145	0	NAp	NAp	([2])	No
146	0	NAp	NAp	8, 2(P)	No
4-in overdrill:					
151	6-1/2(F)	21.0	215	11	No
152	0	NAp	NAp	6-1/2	No
153	8(F)	NAp	NAp	6	No
Starter bit:					
161	0	20.9	292	11-1/2	No
162	0	NAp	NAp	7-1/2	No
163	0	NAp	NAp	6	No

NAp Not applicable. [1]Second cycle, yield unknown. [2]None noted.

NOTE.--F = full; P = partial.

major problem with brand A. Blocks split in 17 out of 25 tests. About one-third of the blocks split with brand B (7 out of 22). Brand C had no block cracking problems when manufacturer-recommended procedures were followed.

It is not certain what significance the block splitting during laboratory tests may have with regard to bolts installed in a massive mine roof. However, it does indicate that high hydraulic pressures are built up in the resin when a bar is forced into a small hole. Further testing should be performed to measure these pressures and to determine if they could cause problems in underground mine installations.

Bad Procedures

The results of the tests using bad procedures are given in tables 10 to 12. For all three brands, the fast insertion took 2 s for a 4-ft bolt. The times for the slow insertion varied with the three different brands. The time was 18 s for brand A, 12 s for brand B, and 17 s for brand C.

The data in tables 10 to 12 show that glove-fingering is more of a problem with

TABLE 10. - Brand A--bad procedures

Procedure and bolt no.	Spin time, s	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked	Comments
Fast (2-s) insert:							
73........	8	11-1/2(F), 5(P).	NAp	NAp	5/8(P)..	No	
74........	7	12(F)...........	22.2	246	NAp.....	No	
75........	7	13(F), 12(P)....	NAp	NAp	7-1/2(F)	No	Resin leaked into crack in block.
76........	7	11(F)...........	NAp	NAp	12(F)...	Yes	
77........	7	8-1/2(F), 6(P)..	NAp	NAp	11(F)...	Yes	Do.
78........	7	16(P)...........	NAp	NAp	9-1/2(F)	No	Partial void from 19 to 27 in up from collar.
79........	8	8-1/2(F)........	NAp	NAp	NAp.....	No	
80........	7	11(F), 11(P)....	23.2	264	2(P)....	No	
81........	8	13(F),11(P).....	NAp	NAp	NAp.....	No	
82........	7	8-1/2(P)........	NAp	NAp	NAp.....	No	
172.......	12	12(F)...........	NAp	NAp	17(F)...	Yes	
Slow (18-s) insert:							
114.......	0	27(F)...........	18.3	243	5-1/2(F)	No	All unmixed and uncured next to bolt; good resin at concrete.
115.......	0	26(F)...........	20.9	330	[1]3(F)...	No	Partially mixed and uncured; hard at concretes, soft under bolt.
116.......	0	24-1/2(F), 6(P).	20.7	298	[1]4(F)...	No	Resin cured and hard.
117.......	0	29-1/2(F).......	NAp	NAp	1(F)....	No	Resin soft and unmixed under plastic; hard and mixed near concrete.
118.......	0	27(F)...........	NAp	NAp	1-1/2(F)	No	Do.

NAp Not applicable. [1]Cracked for 4 in.

NOTE. - F = full; P = partial.

TABLE 11. - Brand B--bad procedures

Procedure and bolt no.	Spin time, s	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked	Comments
Fast (2-s) insert:							
93.......	11	0.....................	21.2	302	8(F)......	No	3-1/2-in partial void from 41-1/2 to 45 in from collar.
94.......	11	0.....................	NAp	NAp	1/2(F), 3(P).	No	
95.......	8	[1]3(F), 2-1/2(F), [2]2(F)	NAp	NAp	1-3/4(F)..	No	
96.......	8	5-1/2(P).............	NAp	NAp	2(P)......	No	
97.......	10	0.....................	22.3	280	1-1/2(F)..	No	
98.......	8	1-1/2(F).............	NAp	NAp	1-1/2(F), 1-1/2(P).	No	
99.......	8	0.....................	NAp	NAp	1(F), 5-1/2(P).	No	
100......	9	0.....................	NAp	NAp	1(F), 1-1/2(P).	No	3 small voids: 1/2 by 1-1/2 in at 31-1/2 in from collar; 3/4 by 1 in at 35 in; 1 by 1 in at 37 in.
101......	8	[2]6(P).................	NAp	NAp	3-1/2(P).	No	
102......	8	0.....................	NAp	NAp	2(F), 3(P)	No	
171......	12	0.....................	NAp	NAp	19-1/2(F).	Yes	
Slow (12-s) insert:							
103......	0	8-1/4(F), 16(P).......	NAp	NAp	4-1/2(F), 7(P).	No	Partially mixed and cured first 26 in; remainder unmixed and uncured.
104......	0	16(F), 10(P)..........	NAp	NAp	3-1/4(F)..	No	Partially mixed and cured first 22-1/4 in; remainder unmixed and uncured.
105......	0	16(F), 9(P)...........	NAp	NAp	4(F)......	No	All unmixed and uncured.
106......	0	15(F), 12(P)..........	10	228	4(F)......	No	Do.
107......	0	25(F).................	18.2	260	9(F)......	No	Mostly unmixed and uncured.

NAp Not applicable. [1]On resin. [2]On bar.

NOTE. - F = full; P = partial.

TABLE 12. - Brand C--bad procedures

Procedure and bolt no.	Glove-fingering, in	Yield load (P_y), kips	Stiffness (K), kips/in	Void at collar, in	Block cracked	Comments
Fast (2-s) insert plus 12-s spin:						
83	0	22.5	289	NAp	No	
84	3/4(P)	23.0	236	1-3/8(F)	No	
85	3(P)	NAp	NAp	NAp	No	
86	3/4(P)	NAp	NAp	2(P)	No	
87	0	NAp	NAp	2-3/4(P)	No	
88	10-1/2(F)	NAp	NAp	2(P)	No	
89	2-3/4(F)	NAp	NAp	NAp	No	
90	15-1/4(P)	NAp	NAp	21-3/4(F)	Yes	
91	3/4(P)	NAp	NAp	22-1/2(F)	Yes	Bulb-shaped pattern of resin in crack, 10-3/4 by 17 in.
92	0	NAp	NAp	2-3/4(F)	No	
170	9-1/2(P)	NAp	NAp	23(F)	Yes	
Slow (17-s) insert:						
108	10(F), 17(P)	NAp	NAp	21(F), 14(P)	Yes	All unmixed and uncured next to bolt.
109	21(F), 6(P)	NAp	NAp	1(F), 20(P)	Yes	Do.
110	24(F)	NAp	NAp	21(F), 3(P)	Yes	Do.
111	25(F)	20	234	6(F)	No	All unmixed and uncured next to bolt; resin cracked and broken from bar 6 in to 23 in from pull collar up.
112	24(F)	2.5	52	1/2(F), 23-1/2(P)	No	All unmixed and uncured next to bolt.
113	24(F)	4.1	138	24(P)	No	Do.

NAp Not applicable.

NOTE. - F = full; P = partial.

either fast or slow insertion than it is when the manufacturers' recommended procedures are used. Table 10 shows that 14 out of 16 tests with brand A had full glove-fingering, and two of the tests had partial glove-fingering. Therefore, every test in the series had some amount of glove-fingering. Of the 16 tests with brand B, 7 had full glove-fingering (table 11). Partial glove-fingerings occurred in four bolts that also had full glove-fingering in another section of the bolt, as well as in two other bolts. Table 12 shows that insertion without rotation of brand C created glove-fingering. Note that installation following the manufacturer's procedure produced no glove-fingering with this brand. With the slow and fast insertion methods of brand C, 8 out of 17 tests had full glove-fingering. Six of these were installed using slow insertion only; the other two occurred using fast insertion. A similar result was observed on brand B, where slow insertion produced glove-fingering on every test.

The pull-test results on bolts installed using the fast-insertion method with 12 s of spinning indicated that all the bolts with all three brands of resin were good. A closer inspection of the data on brand A shows that 12 in of glove-fingering was present on bolt 74, and that bolt 80 had 11 in of full glove-fingering and 11 in more of partial glove-fingering. Despite this evidence of glove-fingering, the pull-test still indicated that the bolt was good. Once again, the test results reinforce the previously drawn conclusion that a pull-test is not an adequate means of evaluating a resin-grouted steel bolt. The visual inspections of brands B and C did not reveal any hidden flaws in the fast-insertion sample.

When only the slow-insertion method was used, all three brands had glove-fingering along almost half of the length of the bolt. The data are shown in tables 10 to 12. Table 10 shows that there were two out of four good pull-tests on bolts installed with the slow insertion procedure. Visual examinations of these bolts indicated that they were very questionable. The resin near the bar was unmixed and uncured, but the resin next to the concrete was good. The results (table 11) for a bolt installed using the slow-insertion method show that the pull-test indicated a possibly poor bolt and that visual examination found a very poor installation with most of the resin unmixed and uncured. Table 12 shows very similar results for the slow-insertion method. One of three pull-tests for the slow insertion indicated a good bolt, but the visual inspections of bolts 111, 112, and 113 found that all three were bad. The results of these eight pull-tests further reinforce the conclusion that a pull test is grossly inadequate for evaluating resin-grouted steel bolts. Based on the results of table 6, if a bolt with more than 12 in of grout column is subjected to a pull test, typically only the yield strength of the steel bar is determined. Adequate pull-test results are no guarantee of satisfactory bolt installation.

The data on cracked blocks (tables 10 to 12) are inconclusive. Brands A and B had minor block cracking (3 out of 13 and 1 out of 16, respectively); but with brand C, the block cracked in 6 out of 17 tests. For brands A and B, none of the blocks split during the slow insertion. With brand C, three of the six splits occurred during slow insertion, while the other three occurred during fast insertion. Once again, the only conclusion that can be drawn from the block-splitting data is that more research is needed.

Straight insertion of the bolt, with or without spinning, increases the probability of having a complete void for several inches at the collar of the hole. However, the data with voids at the collar from any test where a block cracked had to be eliminated. Nevertheless, even with the block splits eliminated, almost all of the tests had 4 in or more of full void at the collar.

TENSION TESTS

The results of 11 tension tests on representative samples of the headed, deformed rebar bolts are given in table 13. ASTM test designation A615-80, "Standard

TABLE 13. - Tension tests on headed, deformed bars

Bar No.	Bar mark	Head mark	Yield point		Ultimate load		Elongation[1]	
			kips	psi	kips	psi	in	pct
3...............	S6S........	84SL	21.85	49,659	33.55	76,250	NAp	NAp
4...............	M6N........	☐ 48USS	21.20	48,182	34.95	79,432	2.10	21.0
5...............	Test bar 10	None	24.0	54,545	37.55	85,341	NAp	NAp
6...............	Test bar 34	S6S	28.7	65,227	46.8	106,364	NAp	NAp
7...............	Test bar 17	None	22.3	50,682	35.15	79,886	NAp	NAp
8...............	Test bar 16	None	23.3	52.955	36.75	83,523	NAp	NAp
9...............	None.......	84SL	23.95	54,432	37.3	84,773	[2]1.22	24.4
10...............	Test bar 23	None	22.75	51,705	36.0	81,818	NAp	NAp
11...............	Test bar 24	6S6	23.95	54,432	37.7	85,682	NAp	NAp
14...............	Test bar 41	None	24.0	54,545	37.4	85,000	NAp	NAp
16...............	M6N........	☐ 48USS	19.9	45,227	36.55	83,068	1.97	19.7

NAp Not applicable. [1]10-in gauge length unless marked otherwise.
[2]5-in gauge length.

Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcing," specifies a minimum tensile strength of 70,000 psi and a minimum yield strength of 40,000 psi for a Grade 40 bar. According to the head markings, all of the rebars tested were Grade 40. Test results show that all bars met the minimum yield, tensile, and 12-pct elongation criteria. The bars with a head mark of ☐ 48USS were used in the main tests (table 13).

CONCLUSIONS

1. Observations made after accidental splits of the test blocks indicated that resin forced into a crack is uncured, uncatalyzed resin that will not bond broken or cracked rock together. Therefore, any resin forced out into fissured rock strata from a cartridge resin bolt will probably not bond the broken strata together, and may actually precipitate splitting.

2. Overspinning of the bolts and the resultant destruction of resin can be a problem; therefore, installation procedures should follow the manufacturer's recommendations for spin time.

3. When the manufacturer-recommended installation procedures are followed, excessive glove-fingering will not be a problem.

4. Users should rigorously observe the 1-yr age limit on any cartridge, and old or broken cartridges should never be used because that will result in unsafe, inadequate bolts.

5. In the Bureau tests involving 4,500-psi concrete blocks, pull-tests on full-column grouted bolts are meaningless if the grouted length exceeds 12 to 16 in. The pull test is only a yield test on the steel bar; it does not indicate the ability of a full-column bolt system to perform satisfactorily.

6. A major amount of glove-fingering was observed with one brand of resin, but only a minor amount was noted with the other two brands. All three brands of resin have been changed since the tests were performed; therefore, these results may not be valid for resin produced at the present time.

7. Either using the starter bit for a 4-ft hole (1-1/16-in-diam bit) or drilling a hole 4 in too long will create similar grout shortages at the collar of the hole (about 8 to 10 in).

8. Slow insertion of the bolt with no spinning at any time during the test produced low pull-test results with brand B and C cartridges but good pull-tests with brand A. The brand A pull-tests were satisfactory even though half or more of the 4-ft bolt was fully glove-fingered. These results confirm that pull-tests are not a satisfactory means for evaluating the support potential of resin-grouted roof bolts.

APPENDIX.--MANUFACTURER-RECOMMENDED INSTALLATION PROCEDURES[1]

BRAND A

1. Push the bolt into the hole to a point just below the roof line. Slow rotation of the bolt during this step is optional.
2. Rotate the bolt rapidly (350-600 rpm) for 10 to 15 s (temperature range 55°-70° F).
3. Push the bolt upward with the maximum thrust available from the machine and hold until the resin hardens. DO NOT ROTATE after previous step because damage to partially gelled resin may result.

BRAND B

1. Position the bolt in the hole and raise the bolt with the drilling machine to within 1 in of the roof.

Alternate method: Position the bolt in the hole and raise the bolt (about 3 in/s) with the drilling machine rotating slowly to within 1 in of the roof.

2. Rotate the bolt for 11 s at approximately 250 rpm. Do not rotate more than 15 s as the resin may start to gel at 15 s at ordinary mine temperature. If it is rotated after the resin begins to gel, the bolt churns the partially hardened resin, which then will not develop full strength.
3. After rotation is stopped, raise the bolt against the roof with full machine thrust and hold until the resin sets up (usually 15 s).

BRAND C

1. With the head of the bolt placed firmly in the chuck of the bolter or in a short spin-in wrench, lift the bolt into the hole using slow to medium rotation. The rate of lift should be 2 to 4 in/s.
2. When the bolt reaches within 1 in of the roof, stop upward movement and fast-spin the bolt, rotating 200 to 450 rpm for 15 to 20 s.
3. Stop rotation and push the bolt upward with the maximum thrust available from the machine and hold until the resin gels.
4. *NEVER* rerotate the bolt after final fast spin has been discontinued to avoid damage to the partially gelled resin.

[1]As of July 1, 1983; may be different at present time. Consult manufacturer prior to installation.

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